

MICROWAVE DRIVEN ACTUATORS POWER ALLOCATION AND DISTRIBUTION

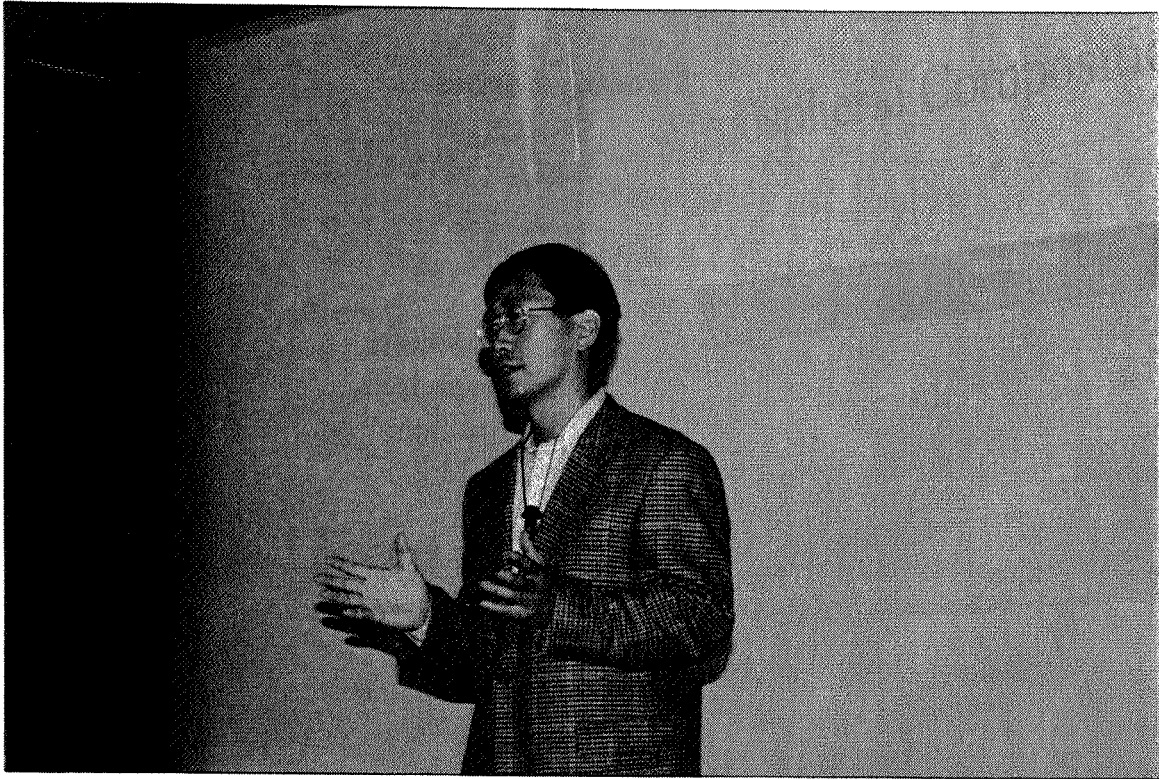
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Key Words: Microwave Driven Actuator, Voltage Up-Converter (VUC), Power Allocation and Distribution (PAD), Rectenna

Prerequisite Knowledge: Understanding of basic electronics principles, and Microwave Driven Actuators.

Objective: Develop a model system that will collect DC voltage from an array of rectenna and propagate the voltage to an array of actuators.

Equipment:

- PSPICE circuit design simulator
- Computer
- Infrared relay systems
- Resistors
- Nine-volt batteries
- Voltmeters
- Proportional Voltage Booster
- Resistors, light emitting diodes, mechanical switches
- 17"x12"x6" aluminum chassis box (2)
- 13.5x1.5" hinge
- Screws and nuts

Abstract

Design, fabrication and test of a power allocation and distribution (PAD) network for microwave driven actuators is presented in this paper. Development of a circuit that would collect power from a rectenna array amplify and distribute the power to actuators was designed and fabricated for space application in an actuator array driven by a microwave. A P- SPICE model was constructed initially for data reduction purposes, and was followed by a working real-world model. A voltage up – converter (VUC) is used to amplify the voltage from the individual rectenna. The testing yielded a 26:1 voltage amplification ratio with input voltage at 9 volts and a measured output voltage 230VDC. Future work includes the miniaturization of the circuitry, the use of microwave remote control, and voltage amplification technology for each voltage source.

Introduction

The development of microwave driven smart materials has caused a need for on – board power allocation and distribution to control individual rectenna. Microwave driven smart materials technology has been developed as a remote, wireless method of powering smart materials, specifically piezo-actuators for the Next Generation Space Telescope (NGST). Due to this fact, a power allocation and distribution (PAD) circuit must be integrated with the power source. Rectenna is a material that when bombarded with microwaves of certain frequency, generates voltage. This voltage must be collected, distributed, and amplified to control piezoelectric displacement actuators. The power allocation device and VUC integrated design makes this possible

Circuit Description (PSPICE model)

The power allocation circuit (PAC) is a model of a voltage distribution network used to collect and distribute DC voltage to a system of piezoelectric actuators as shown in Fig. 1. The design was tested and refined using PSPICE ICAP's 4Rx-circuit simulator. Stage one includes six nine-volt batteries and twelve solid-state switches (Fig 1a). Each set of switches represents relays (ICAP 4rx's parts library does not include relays) used to turn sources on or off. Stage two is a step-up transformer with a 26:1 voltage amplification ratio, which represents the voltage up – converter (Fig 1b). Stage three is a parallel network that includes nine switches and nine identical circuits; a resistor and capacitor in series (Fig 1c). The resistor and capacitor represent the electrical equivalent of a piezoelectric actuator.

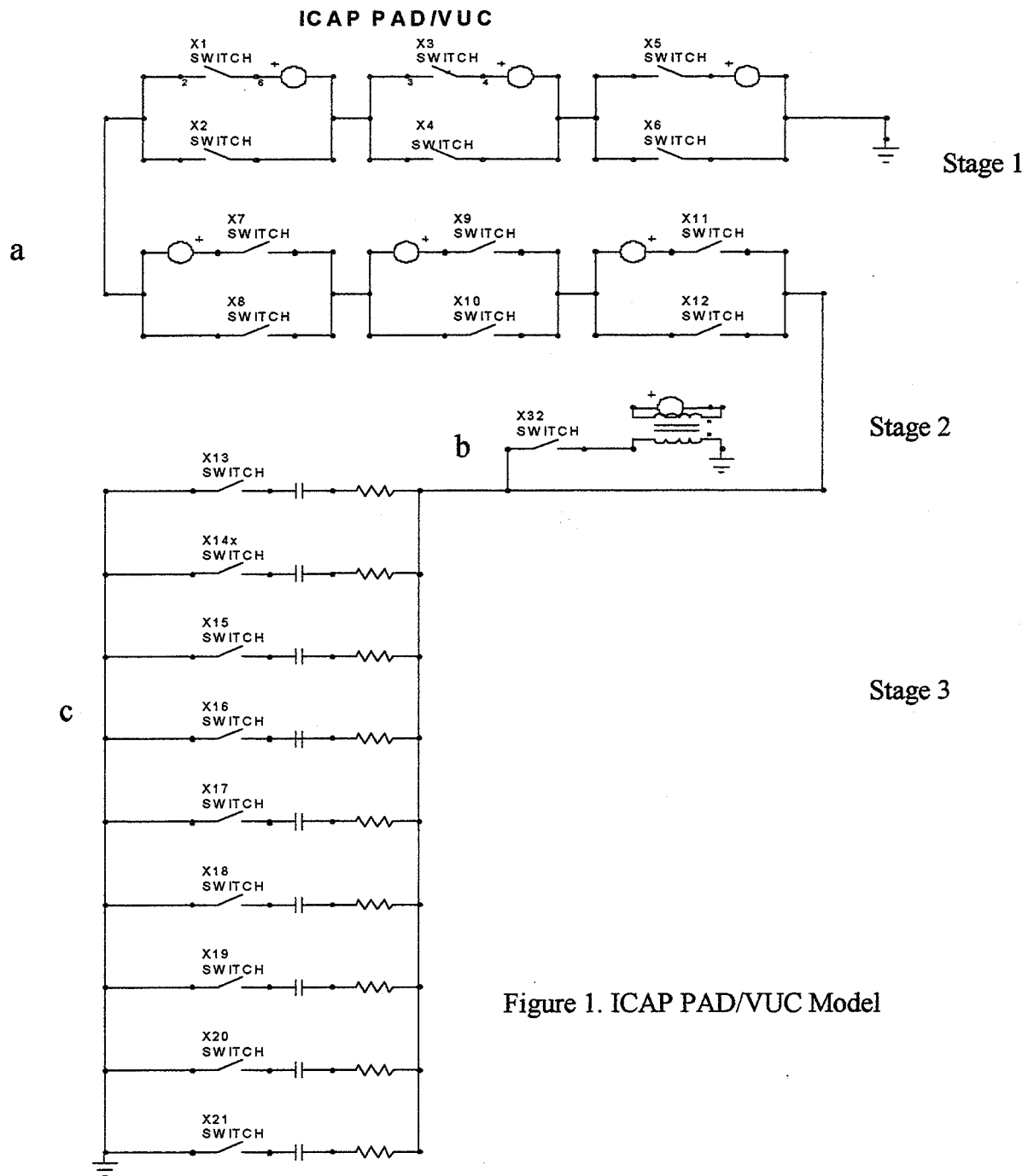


Figure 1. ICAP PAD/VUC Model

Theory of Operation (PSPICE model)

The power allocation model generally consists of stages one and two (Fig. 1a & b). Stage one provides a range of 9 to 54 volts DC in 9 - volt increments to the actuator array. The maximum voltage is achieved by linking voltage sources V1 –V6 in a series mode. V1 through V6 are each 9 – volt DC cells. Operating conditions with all sources on are X1

– X11 odd on, X2 – X12 even off. The actuator array is a parallel network (Fig 1c). The voltage across each branch is constant. All equivalent circuits may operate simultaneously, separately or in any combination. Switches S13 through S21 determine the on or off state of the equivalent circuits. The equivalent circuits represent piezoelectric actuators. DC operating point analysis is used to obtain data.

Voltage Up - Converter Circuit

The Voltage Up - Converter (VUC) circuit in the PSPICE simulator consists of a voltage booster (step - up transformer) and a voltage divider circuit. The transformer ratio is 26:1, in effect a voltage multiplier. The divider circuit is used to maintain a constant voltage across the array. The voltage divider circuit consists of a load resistor that is placed across the actuator array, and a potentiometer in series with the array. This configuration forms the voltage divider. Knowing that voltage is the same across parallel components, the voltage across load resistor will also be across the actuator array. The potentiometer is used to change the total resistance of the circuit as the output voltage from the voltage booster changes. As the total resistance of the divider decreases, the greater part of the voltage will drop across the load resistor. The potentiometer makes this possible. The voltage divider rule explains the relationship between voltage and resistance in a voltage divider circuit;

$$V_1 = R_1 V_o / R_t$$

Where V_1 is voltage across the load resistor, R_1 is a constant load resistance, V_o is the output voltage from the transformer, and R_t is the total resistance of the divider.

Equivalent Circuits

Figure 2 shows the equivalent circuit used in the power allocation and distribution circuit, a piezoelectric displacement actuator. Equivalent circuits for piezoelectric actuators vary by manufacturer. The difference between equivalent circuits is usually the state or mode of the actuator e.g. loaded, not loaded etc. Arbitrary values were used for ICAPs equivalent circuit.

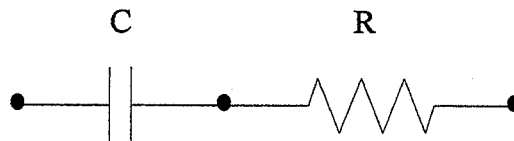


Figure 2. Actuator Equivalent Circuit.

Real World Model

The real world integrated PAD/VUC model functions in the same way as the ICAP's model. The real-world model mainly consists of a Vellman IR controlled fifteen – channel relay system, a Morgan Matroc IR controlled relay system, a proportional voltage booster from Piezo Systems, and three panel mount multi-meters. Six nine-volt batteries produce the voltage, and the VUC is powered by one nine-volt battery. Actuators are represented by green light emitting diodes and Rectenna (voltage sources) are represented by red LED's. Voltage sources and actuators are independently controlled by relays. The VUC is also controlled remotely by an independent IR channel and relay (Morgan Matroc Proportional voltage booster shown in Fig 3). The configuration of the PAD/VUC system is shown in Fig. 4.

Technical Issues

- Miniaturization

1. For conservation of space the PAD/ VUC will be produced at the microchip level
2. Fabrication would be specific to NASA Langley Research Center
3. Increased system reliability
4. Convenience
5. Increased speed and ease of production

- Infrared Interaction

1. 15 channel IR system produced by Vellman
2. Infrared remote control of relay state

- Microwave Remote Control

1. Eventually microwave RF will be used in stead of IR
2. Microwave allows for greater distance than IR.
3. RF control signal may be piggy backed along main wave
4. Development of multi – channel microwave system is needed.

- PAD/VUC – Circuit Interfacing
 - 1. Circuit creates a common bus for each rectenna.
 - 2. Circuit can be imbedded in rectenna array.
 - 3. Allows bypassing or summing of rectenna power outputs.

Conclusions

During summer research at NASA Langley Research Center through the FAR Grant (NCC-1-280), development of a power allocation and distribution circuit (PADC) was completed. Testing yielded maximum values of voltage at 54 VDC using six nine-volt cells. Future work includes interfacing and testing of the circuitry with Rectenna fabricated at NASA Langley. Testing aims to discover data such as design efficiency, maximum voltage and current levels, as well as maximum power values.

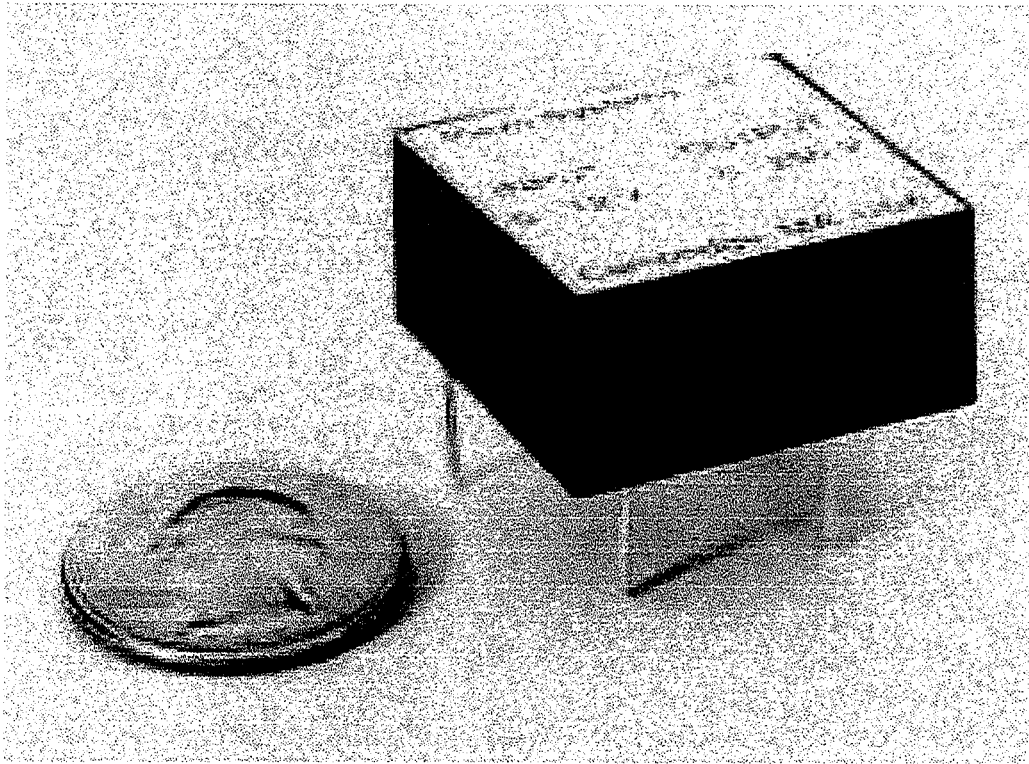


Figure 3 Morgan Matroc Proportional Voltage Booster

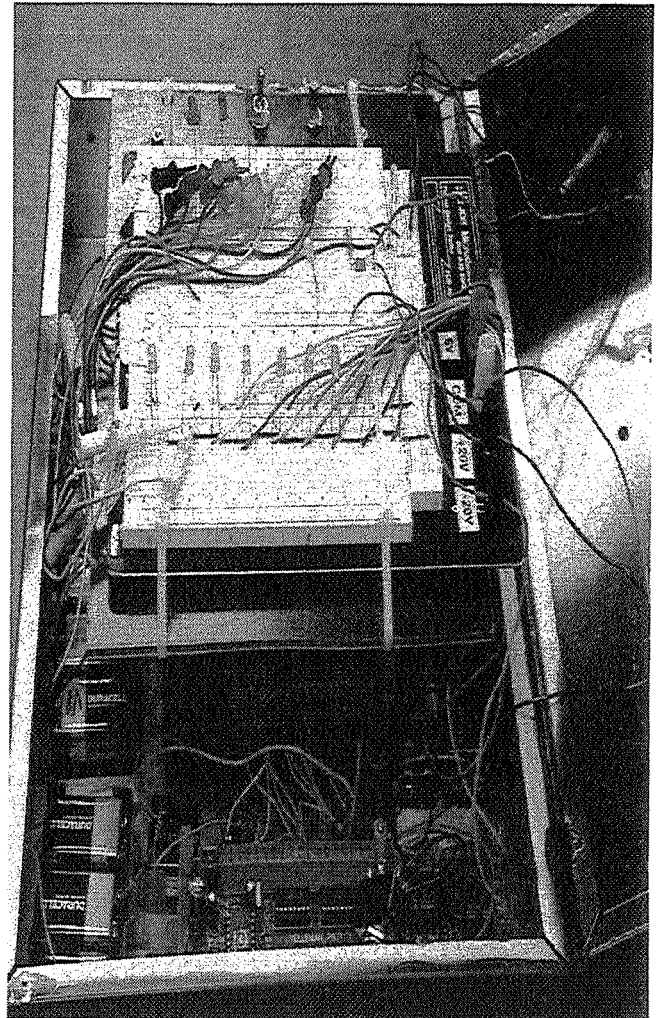
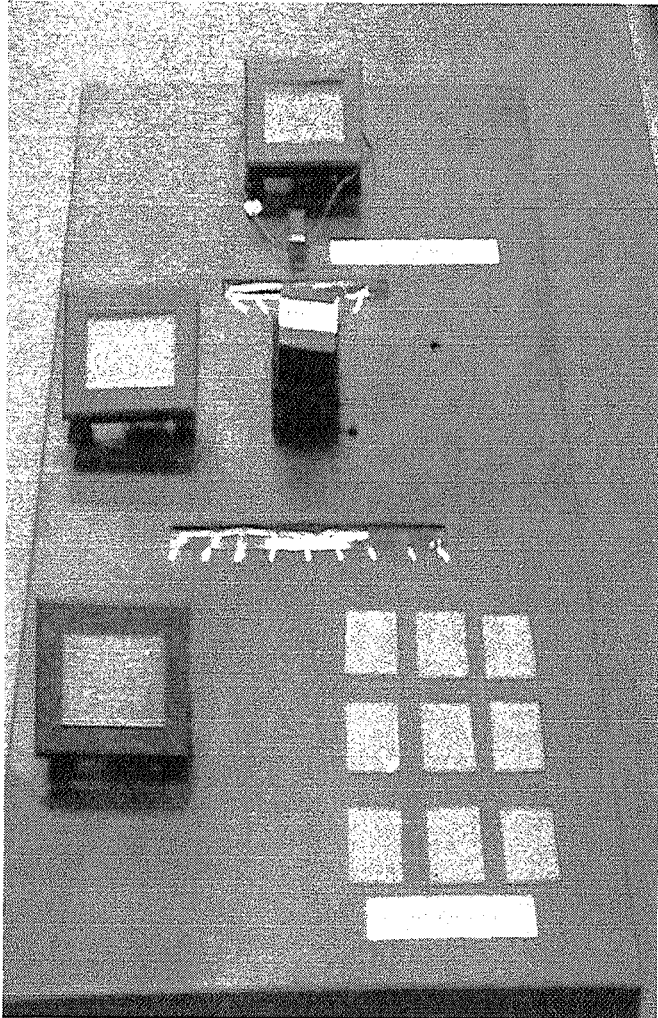


Fig. 4. Configuration of PAD/VUC System